FIREMON Introduction

THE AUTHORS

Duncan C. Lutes is a Research Forester with Systems for Environmental Management, stationed at the USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Lab, P.O. Box 8089, Missoula, MT 59807; phone: 406.329.4761; FAX: 406.329.4877; e-mail: dlutes@fs.fed.us. He has a B.S. and M.S. degree in forestry from the University of Montana, Missoula. His background is in fuels, principally coarse woody debris, primarily studying spatial and temporal distributions. He has been involved in the development of the First Order Fire Effects Model and several Fire and Fuels Extension variants to the Forest Vegetation Simulator. He is the Technical Editor and contributing author for this publication.

Robert E. Keane is a Research Ecologist with the USDA Forest Service, Rocky Mountain Research Station at the Fire Sciences Laboratory, P.O. Box 8089, Missoula, MT 59807; phone: 406.329.4846; FAX: 406.329.4877; e-mail: rkeane@fs.fed.us. Since 1985, Bob has conducted ecological research into fuel dynamics, ecosystem simulation, ecosystem restoration, and spatial modeling for the Fire Effects project. His most recent research includes 1) developing ecological computer models for exploring landscape, fire, and climate dynamics, 2) the mapping of fuel characteristics for spatially explicit fire growth and fire effects evaluation, 3) synthesis of a First Order Fire Effects Model to predict the direct consequences of a fire, 4) exploring the ecology and restoration of whitebark pine in the Northern Rocky Mountains, and 5) classification and simulation of vegetation communities on the landscape using GIS and satellite imagery. He received his B.S. degree in forest engineering from the University of Maine, Orono; his M.S. degree in forest ecology from the University of Montana, Missoula; and his Ph.D. degree in forest ecology from the University of Idaho, Moscow.

John F. Caratti is a Systems Ecologist with Systems for Environmental Management, P.O. Box 8868, Missoula, MT 59807; phone: 406.549.7478. Since 1988, John has developed computer software for ecological data analysis and wildlife population modeling. His most recent work includes developing database applications for georeferenced field data, vegetation classification and mapping, and fire effects monitoring. He received his B.A. degree in ecology from the University of California, San Diego, in 1988, and his M.S. degree in wildlife biology from the University of Montana in 1993. John has worked as an ecologist with the USDA Forest Service, Northern Region, a quantitative ecologist with The Nature Conservancy, and as an independent contractor.

Carl H. Key is a Geographer with the USDI U.S. Geological Survey at the Northern Rocky Mountain Science Center, Glacier Field Station, West Glacier, MT 59936; phone: 406.888.7991; FAX: 406.888.7990; e-mail: carl_key@usgs.gov. Carl developed the Geographic Information System currently used by Glacier National Park, and continues to support its application and advancement. Since 1976 he has coordinated and conducted several studies in fire ecology, land type classification, exotic plants, biological monitoring, and satellite telemetry. He also contributed to various other wildlife studies, has advanced software development, and technology transfer, and has consulted on management issues for the National Park Service and other agencies. He was instrumental in establishing the global change research program at Glacier in the early 1990s. Since 1996, he has been researching the characteristics of fire severity using remote sensing, and helping to implement burn assessment on a national level.

Nathan C. Benson is a Fire Ecologist with the USDI National Park Service at the Natural Resource Program Center, 1201 Oak Ridge Drive, Suite 200, Fort Collins, CO 80525-5596; phone: 970.267.2121; FAX: 970.225.3585; e-mail: nate_benson@nps.gov. Nate has worked for the National Park Service for more than 15 years in a variety of positions. He started his NPS fire career as a fire effects monitor at Glacier National Park, and then moved to Yellowstone and Great Smoky Mountains National Parks as a Fire Use Module Leader. Most recently he was the Prescribed Fire Specialist at Everglades National Park and is currently working for the NPS Fire Management Program Center as a Fire Ecologist. Since 1996, he has worked with Carl Key on researching characteristics of fire severity using remote sensing and has been the lead for the National Park Service in developing the National Burn Severity Mapping Project, a cooperative project between the National Park Service and U.S. Geological Survey. Nate has an M.S. degree in land resources from the University of Wisconsin-Madison's Institute for Environmental Studies.

Steve Sutherland is a Research Ecologist with the Fire Effects Project at the USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, P.O. Box 8089, Missoula, MT 59807; phone: 406.329.4813; FAX: 406.329.4877; e-mail: ssutherland@fs.fed.us. Since joining the lab, he has been involved with the Southern Utah Fuels Management Demonstration Project, expanding weed summaries for the Fire Effects Information System, and researching Postfire Weed Response in western Montana. Before joining the Fire Lab, Steve was the State Ecologist for the Ohio Chapter of The Nature Conservancy where he oversaw the plant community and rare species monitoring program. Prior to that, he was an Assistant Research Professor in the Department of Biology at the University of Utah. He received B.S. and M.S. degrees in forestry from Utah State University, a Ph.D. degree in evolutionary ecology from the University of Arizona, and a postdoctoral fellowship in population genetics from the University of Utah.

Larry H. Gangi is a Programmer with Systems for Environmental Management, P.O. 8868, Missoula, MT 59807; phone: 406.549.7478. Larry has developed software for a variety of natural resource applications including fire modeling, ecological survey data analysis and conversions, timber stand, and water resources. He received his B.S. and M.S. degrees in computer science from the University of Montana, Missoula.

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EXECUTIVE SUMMARY

Monitoring and inventory to assess the effects of wildland fire is critical for 1) documenting fire effects, 2) assessing ecosystem damage and benefit, 3) evaluating the success or failure of a burn, and 4) appraising the potential for future treatments. However, monitoring fire effects is often difficult because data collection requires abundant funds, resources, and sampling experience. Often, the reason fire

monitoring projects are not implemented is because fire management agencies do not have scientifically based, standardized protocols for inventorying pre- and postfire conditions that satisfy their monitoring and management objectives. We have developed a comprehensive system, called the ***Fire Effects Monitoring and Inventory System (FIREMON)***, which is designed to satisfy fire management agencies' monitoring and inventory requirements for most ecosystems, fuel types, and geographic areas in the United States. FIREMON consists of standardized sampling methods and manuals, field forms, database, analysis program, and an image analysis guide so that fire managers can 1) design a fire effects monitoring project, 2) collect and store the sampled data, 3) statistically analyze and summarize the data, 4) link the data with satellite imagery, and 5) map the sampled data across the landscape using image processing. FIREMON allows flexible but comprehensive sampling of fire effects so data can be evaluated for significant impacts, shared across agencies, and used to update and refine fire management plans and prescriptions.

The key to successful implementation of FIREMON requires the fire manager to succinctly state the objectives of the proposed fire monitoring project and accurately determine the available monitoring or inventory project resources. Using this information, the manager uses a series of FIREMON keys to decide the sampling strategy, methods, and intensity needed to accomplish the objectives with the resources on hand. Next, the necessary sampling equipment is gathered and dispersed to sampling crews. Field crews then collect FIREMON data using the detailed methods described in this FIREMON documentation. Collected data are then entered into a Microsoft® Access database. These data can be summarized, analyzed, and evaluated using the set of integrated programs developed specifically for FIREMON.

FIREMON has a flexible structure that allows the modification of sampling methods and local code fields to allow the sampling of locally important fire effects evaluation criteria.

INTRODUCTION

We have developed a comprehensive ***Fire Effects Monitoring and Inventory System***, called ***FIREMON***, that integrates new and current ecological field sampling methods with remote sensing of satellite imagery to assess the effects of fire on important ecosystem components. The primary objective of FIREMON is to measure the immediate and long-term effects of a planned or unplanned fire on critical ecosystem characteristics so that fire managers can evaluate the impact of that fire on ecosystem health and integrity. This information can be used to refine fire management plans and prescriptions. This system is NOT used to document the behavior of the fire, but rather it is used to record the consequences of the fire on the landscape.

We used the National Park Service Fire Monitoring Handbook (FMH) (USDI NPS 2001) and the ECODATA Handbook (Hann and others 1988) as the framework for designing FIREMON sampling methods. However, we extended the utility of these protocols by providing nested levels of sampling intensity coupled with sampling flexibility. We designed FIREMON so that most of the data collected with FIREMON procedures will be compatible with other monitoring and inventory systems such as FMH and Natural Resource Information System (NRIS) databases. Additional sampling methods can be easily added to FIREMON as fire managers recognize their relevance in regard to inventorying and monitoring fire effects. A method to monitor water quality, for instance, would be a useful addition to the group of FIREMON sampling protocols.

Monitoring is the critical feedback loop that allows fire management to constantly improve prescriptions and fire plans based on the new knowledge gained from field measurements. *Inventory* is the description and quantification of important ecosystem and landscape elements and is critical to fire management activities for planning, prioritizing, and designing prescribed fire activities.

Monitoring the effects of wildland fire is critical for 1) documenting extent of fire effects, 2) assessing ecosystem damage and benefit, 3) evaluating the success or failure of a prescribed burn, 4) appraising the potential for future treatments, and 5) prioritizing stands for fire treatment. Objectives for monitoring depend on the type of fire. Wildfire monitoring is necessary to evaluate the possible need for rehabilitation or to assess a fire's potential impact to the ecosystem, while monitoring prescribed fires is invaluable for assessing the efficacy of the treatment. Monitoring data can have far-reaching applications in fire management because they provide the scientific basis for planning and implementing future burn treatments. Moreover, this information documents important fire effects, which can be used by other districts, agencies, and countries for their projects. Measuring postfire ecosystem response also allows us to understand the consequences of fire on important ecosystem components and share this knowledge in a scientifically based language.

Despite its importance, it is often a challenge for fire managers to install effective monitoring programs due to resource limitations inherent in time, money, people, and expertise. Also, often fire managers find themselves too busy with other essential duties to design and implement monitoring projects. And the perceived complexity of monitoring sampling designs has often overwhelmed or intimidated some fire managers. The issue of complexity is especially true when the fires to be monitored are large (greater than 1,000 acres), occur on diverse landscapes, and have complex severity patterns. Moreover, it is difficult to design a cost-efficient sampling strategy that will quantify stand- and landscape-level fire effects across an entire landscape using scientifically credible methods. But perhaps the main reason most fire monitoring projects never become implemented is the lack of standardized and comprehensive sampling methods and tools easily available to fire managers. Most fire management agencies do not have the scientifically based sampling protocols for inventorying pre- and postfire conditions to satisfy monitoring objectives. (The USDA Forest Service Monitoring and Evaluation Working Paper dedicates only one paragraph to data collection methods.) The major exception is the USDI National Park Service, which has extensive guidelines and protocols for sampling ecosystem characteristics that are important to monitoring fire effects (National Park Service 2001, http://www.nps.gov/fire/fire/fir_eco_firemonitoring.html). Collecting field data is easily the most expensive part of any monitoring and evaluation project, requiring extensive expertise in field sampling, fire and landscape ecology, and sampling methods design. Perhaps the single greatest challenge of designing a fire monitoring project is matching existing funding, personnel, and equipment with monitoring objectives to achieve scientifically credible evaluation data.

Monitoring is an extremely complex task that requires an extensive assessment of many ecosystem characteristics across multiple time and space scales. Fire effects monitoring, in this approach, does not include documentation of the behavioral characteristics of the fire, but rather the sampling of the ecosystem characteristics that are directly affected by the fire. These fire effects can be described at the plant level (mortality), at the stand level (fuel composition, species composition), and at the landscape level (patch dynamics, burn severity mosaic). Moreover, fire effects can be described over many timeframes including immediate (directly after fire), short (1 to 5 years postfire), or long (10 to 100 years postfire) term measurements. A valid sampling strategy for monitoring fire effects must provide for the integration and linkage of ecosystem response across these multiple time and space scales to provide meaningful data to fire management. Our intent in developing FIREMON is not to replace current systems of fire severity assessment, but rather to augment these efforts with a comprehensive and flexible set of recognized field and office methods.

It would be impossible, and probably inefficient, to design a fire monitoring program to include the measurement of all possible information a fire manager in any part of the United States would want to monitor. For instance, fire managers in the Western United States may not need a measurement, such as depth to water table, but this measurement might be absolutely critical to Eastern United States managers. Therefore, we have included local code fields in FIREMON that allow the manager to include other measurements that describe the macroplot. For example, hiding cover (horizontally projected plant cover) may be an important criterion in setting the objectives for a prescribed burn, so the manager could develop a coding system and use one of the FIREMON local code fields to assess hiding cover.

As managers attempt to oversee broader and broader areas for fire, fire effects information is increasingly difficult to obtain. Direct observation may be largely impeded by fire size, remoteness, and rugged terrain, and there may be little chance for sufficient reconnaissance on the ground. In some cases, the sheer number of areas to evaluate in one fire season is overwhelming. In others, managers with regional responsibilities may need to aggregate information from many districts to report their burn results, or to develop integrated plans. For circumstances such as these, FIREMON offers a section on Landscape Assessment (LA), which primarily addresses the need to identify and quantify fire effects over large areas, involving potentially many burns and covering tens of thousands of acres at a time. It incorporates remote sensing and GIS technologies that can produce a variety of derived products such as maps, images, and statistical summaries. The ability to compare results is emphasized, along with capacity to aggregate information across broad regions over time.

Landscape Assessment shows the spatial heterogeneity of burns, and how fire interacts with vegetation and topography, providing a *quantitative* picture of the whole burn as if viewed from the air. The quantity measured and mapped is "burn severity," defined here as a scaled index gauging the magnitude of ecological change caused by fire. In the process, two methodologies are integrated. One, the Normalized Burn Ratio (NBR), involves remote sensing using Landsat 30-m data and a derived radiometric value. The NBR is temporally differenced between pre- and postfire datasets to spatially determine the degree of change detected from burning. The other methodology, the Composite Burn Index (CBI), adds a complimentary field sampling approach. It entails a relatively large plot with independent severity ratings for individual strata within the community and a synoptic rating for the whole plot area. Plot sampling may be used to calibrate and validate remote sensing results, or it may be implemented as a stand-alone field survey for individual site assessment

GENERAL DESCRIPTION

What FIREMON Is…

FIREMON consists of a standardized set of sampling manuals, databases, field forms, analysis programs, and image analysis tools that will allow the manager to design and implement a fire effects monitoring project. To use FIREMON, a fire manager must first succinctly state the objectives of the proposed fire monitoring project. Then the manager must decide the amount of resources available to successfully conduct the project. Using this information, the manager goes to a series of FIREMON keys to decide which methods to use to accomplish the objectives, and the sampling strategy to employ to implement these methods across the landscape. Results from these keys are then used to design the fire monitoring project using FIREMON guidelines and procedures. Sampling equipment and plot forms are gathered and dispersed to sampling crews. The field crews then collect FIREMON data using the detailed methods described in this FIREMON publication. Collected data are then entered into a standardized database using Microsoft® Access software. These data are then summarized, analyzed, and evaluated using the set of FIREMON programs provided by this publication.

FIREMON is designed to be robust by being flexible. It allows fire managers to design a sampling strategy where only those ecosystem measurements of the greatest concern are measured. But FIREMON will still provide a myriad of comprehensive and detailed sampling schemes to measure the many important fire-related ecosystem elements. Sampling design focuses on wildland fire use objectives, rather than a shotgun approach where all ecosystem characteristics are measured to quantify ecosystem change. FIREMON is designed to be applicable for most land areas or ecosystems in the United States.

FIREMON is structured so that it can be easily learned. First, FIREMON resides on an Internet Web site so that it will be easily accessible to all. Second, the entire FIREMON system, including sampling methods, field forms, and databases, are available on CD so that it can be accessed from any computer with Microsoft Word and Access installed (versions 2000 and later). Finally, training courses have been developed to teach FIREMON to fire personnel with limited sampling experience.

What FIREMON Is NOT…

To fully understand FIREMON, it is important to emphasize what FIREMON is NOT:

FIREMON is NOT intended to be a corporate database, although it surely could be at some point in the future.

FIREMON is NOT a replacement for FMH in the National Park Service or the NRIS protocols developed by the Forest Service. FIREMON can complement these systems and provide additional help with monitoring tasks.

FIREMON does NOT contain software for extensive data analysis. FIREMON software will provide a general report and statistical summary, but not extensive statistical analyses. More extensive analysis can be accomplished by exporting the data from FIREMON and using them in a statistical package. Also, additional statistical analysis can be added at a later date.

FIREMON is NOT used to document fire behavior; it is used to record the consequences of the fire on the landscape.

FIREMON is NOT just a fire monitoring package. Many procedures and the database within FIREMON are useful for other ecosystem inventory and monitoring. One inventory need we especially included in FIREMON is fuels. FIREMON contains the necessary components for sampling surface fuels for inventory, fuels mapping reference (ground-truth), and fuels summary for input to fire behavior and effects programs.

FIREMON does NOT include sampling methods for all important fire effects. For example, changes in water quality may be an important fire effects issue, but there is no water quality sampling protocol in FIREMON. The sampling methods in FIREMON were written using existing, recognized sampling methods. We were unable to find a standardized protocol for water quality sampling, so we did not include one. However, new sampling methods can be readily added into FIREMON in the future.

The Four FIREMON Components

There are four major components to FIREMON:

1) **Integrated Sampling Strategy**—This is a set of step-by-step procedures for designing fire effects sampling projects. This component is composed of design keys, strategy descriptions, and guidelines for designing a successful fire monitoring project.

2) **Field Methods**—These are methods for sampling important ecosystem characteristics used to assess fire effects. There are currently 10 methods implemented into FIREMON: Plot Description (PD), Tree Data (TD), Fuel Load (FL), Species Cover (SC), Cover/Frequency (CF), Line Intercept (LI), Density (DE), Point Intercept (PO), Rare Species (RS), and Composite Burn Index (BI). These sampling methods provide a complete set of field sampling protocols to quantify changes in ecosystem characteristics due to fire to describe stand-level fire effects. Additionally, there are two database tables to record metadata (MD) information and fire behavior (FB).

   The Landscape Assessment component details how remotely sensed imagery can be used to design a spatially explicit strategy to locate, collect, and summarize field data across a burned landscape. These methods require extensive expertise in the processing of remotely sensed imagery.

3) **FIREMON Database**—Field data are stored in the Microsoft® Access-based FIREMON database. Data entry forms look like field forms, and drop down lists limit data entry errors.

4) **Analysis Tools**—These include queries in the FIREMON database for producing plot-level data summaries, and the FIREMON Analysis Tools (FMAT) software for analyzing collected field data. The FMAT program provides data summaries for either plot-level or grouped plots and statistical inference of grouped plots using Dunnett's procedure for multiple comparisons with a control. This test is designed to statistically compare pre- and posttreatment data.

The fire manager can choose to perform all or part of one or more components, but the real power of FIREMON is in the integration of all components to describe fire effects at multiple scales.

Integrated Sampling Strategy

The Integrated Sampling Strategy (ISS) component provides the manager with step-by-step instructions on how to design a comprehensive, statistically valid field sampling effort for the purpose of quantifying fire effects over long periods across burned landscapes. This component describes how the detailed sampling procedures are selected, and how to place sample plots across project area. This will allow the fire manager to design a sampling procedure to implement on preburn or postburn areas for describing the effect of the wildfire or prescribed fire.

As in any project, there are three ways to get things done: good, fast, and cheap. But a fact of nature says we cannot accomplish these three goals simultaneously; one can only effectively manage for one and compromise on the remaining two. Therefore, the ISS has a three-level, hierarchically nested strategy for implementing each sampling method in the field assessment. This three-level strategy is geared toward a number of important sampling considerations that attempt to provide a compromise between good, fast, and cheap:

1. **Level I—Simple sampling scheme**. Fastest and cheapest while still collecting useful data in the context of the management objective. Use this scheme if little time, money, or personnel are available to complete the monitoring tasks.
2. **Level II—Recommended sampling scheme**. Somewhat fast, somewhat cheap, and somewhat good. Statistically valid data collected as efficiently as possible but with high levels of variability. Use this scheme if defensible numbers are needed from the monitoring effort, but there is limited time and/or resources.
3. **Level III—Detailed sampling scheme**. Real good but slow and somewhat costly. Statistically valid data with minimized levels of variation but with high collection costs. Use this scheme if the most statistically valid estimates are needed and time and money are not limiting.

These three sampling levels can be used at two spatial levels. The fire manager must pick the sampling level to assign to monitor the landscape and the sampling level to monitor the stands. For example, the land manager may not care about fire effects across the landscape, such as in a prescribed burn, but cares more about stand level changes across the burn unit. In this case, the fire manager would decide on Landscape Level I with Stand Level III. However, another fire manager may not care how a wildfire burned at the stand level, but wants to know general characteristics of how the fire burned across the landscape. In this case, Landscape Level II or III would be selected while Stand Level I or II might be selected, depending on time and resources.

Field Assessment

The field assessment portion of FIREMON contains an extensive set of procedures for sampling important ecosystem characteristics before and after a prescribed or natural fire for ecosystems in the United States, including forests, grasslands, and shrublands. The design of FIREMON is such that the fire manager can tailor the field measurement procedures to match burn objectives or wildland fire use concerns. Moreover, the fire manager can scale the intensity of measurement to match resource and funding constraints. For example, to document tree mortality, the fire manager might choose one of three hierarchically nested sampling procedures, where the first procedure might provide general descriptions of tree mortality quickly at low cost (photopoints, walk-through), while the third procedure would document, in detail, individual tree health and vigor, to generate comprehensive data applicable to many analyses but costly to collect. A key has been developed to help fire managers decide the appropriate methods and sampling intensity for each.

The field assessment procedures are written into a handbook that can be taken into the field. The assessment is composed of 1) field methods, 2) plot forms, 3) cheat sheets, and 4) equipment lists. This assessment does not include details on how certain sampling procedures are selected; those details are in the ISS section.

FIREMON contains the following sampling procedures for monitoring ecosystem characteristics:

Plot Description (PD)—A generalized sampling scheme used to describe site characteristics on the FIREMON macroplot with biophysically based measurements.

Tree Data (TD)—Trees and large shrubs are sampled on a fixed-area plot. Trees and shrubs less than 4.5 ft tall are counted on a subplot. Live and dead trees greater than 4.5 ft tall are measured on a larger plot.

Fuel Load (FL)—The planar intercept (or line transect) technique is used to sample dead and down woody debris in the 1-hour, 10-hour, 100-hour, and 1,000-hour and greater size classes. Litter and duff depths are measured at two points along the along the base of each sampling plane. Cover and height of live and dead, woody and nonwoody vegetation is estimated at two points along each sampling plane.

Species Composition (SC)—Used for making ocular estimates of vertically projected canopy cover for all or a subset of vascular and nonvascular species by diameter at breast height (DBH) and height classes using a wide variety of sampling frames and intensities. This procedure is more appropriate for inventory than monitoring.

Cover/Frequency (CF)—A microplot sampling scheme to estimate vertically projected canopy cover and nested rooted frequency for all or a subset of vascular and nonvascular species.

Point Intercept (PO)—A microplot sampling scheme to estimate vertically projected canopy cover for all or a subset of vascular and nonvascular species. Allows more precise estimation of cover than the CF methods because it removes sampler error.

Density (DE)—Primarily used when the fire manager wants to monitor changes in plant species numbers. This method is best suited for grasses, forbs, shrubs, and small trees that are easily separated into individual plants or counting units, such as stems. For trees and shrubs over 6 ft tall the TD method may be more appropriate.

Line Intercept (LI)—Primarily used when the fire manager wants to monitor changes in plant species cover and height of plant species with solid crowns or large basal areas where the plants are about 3 ft tall or taller.

Rare Species (RS)—Used specifically for monitoring rare plants such as threatened and endangered species.

Landscape Assessment (LA)—Useful for mapping fire severity over large areas. Combines a ground-based burn severity assessment, the **Composite Burn Index (BI)** and a satellite derived remote sensing analysis method, the **Normalized Burn Ratio (BR)**. The LA methodology will assist in determining landscape level management actions where fire severity is a determining factor. See below for more information.

Each sampling method is discussed in detail in their respective sections. Additional sampling methods can be easily added to FIREMON as fire managers recognize their relevance.

Landscape Assessment

The remote sensing of severity is captured by a new Landsat TM radiometric index we call the Normalized Burn Ratio, or NBR. The NBR evolved through sampling of TM band reflectance over burned surfaces, and was tested against three other TM measures appearing in the literature. Multitemporal differencing was employed to enhance contrast and detection of changes from before to after fire. Seasonal effects also were tested to determine the best time of year for TM data acquisition. Based on statistical and visual characteristics, NBR difference from early growing season dates was judged to be optimal, compared to other measures. Results clearly showed the extent of burning that represented a wide range of severity magnitude that was easily interpreted for each burn. Further, the full range of differenced NBR can be stratified into a finite number of ordinal severity levels, to facilitate summation of burns through mapping and tabular statistics. Those data provide a basis for monitoring burn impacts over large regions, and for comparing burns spatially and temporally.

Sensor characteristics make this approach suitable for moderate resolution (30-m) applications that require more extensive and precise information than rapid assessment techniques, and can be completed within a 1-year timeframe of the subject fire.

FIREMON DOCUMENTATION STRUCTURE

FIREMON is presented using a series of sections to document the entire fire effects monitoring system. This set of documents is not necessarily designed to be read from front to back like a book, but rather it is designed for FIREMON users to read only those sections that are important to their sampling requirements. Every FIREMON user should read the Integrated Sampling Strategy (ISS) because it contains absolutely essential FIREMON sampling concepts and terminology that are used throughout all documents.

There is an obvious lack of citations in the bulk of FIREMON documentation. This was done on purpose to reduce clutter and improve readability. This does not mean that we didn't consult numerous sampling and monitoring texts during the development of FIREMON. The References sections contain citations for the journal articles, textbooks, reference books, and symposium proceedings used designing and developing FIREMON.

FIREMON also includes a glossary that defines common FIREMON terminology, and a How To… section that describes sampling techniques used in more than one of the FIREMON sampling methods.

We attempted to design FIREMON document structure so that major and minor headings describe critical monitoring tasks. This way, the FIREMON user can easily jump to a particular method or procedure instead of having to read the entire document. For this to work, each heading section must effectively stand on its own so the user does not have to read other sections to understand the section of interest. A side effect of this independent section treatment is that there is often redundant text across sections that may be annoying to those reading each section sequentially. We apologize for this repetition and hope you will recognize its purpose.